13th International Symposium on Automotive Lighting

Darmstadt
September 23–25, 2019

TECHNISCHE UNIVERSITÄT DARMSTADT

ISAL 2019

Tran Quoc Khanh (Hrsg.)

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13th International Symposium on Automotive Lighting

Steering Board

Foreword

It is a pleasure to present you the proceedings of the 13th International Symposium on Automotive Lighting, which takes place in Darmstadt on September 23-25, 2019. This conference is the document of a series of successful conferences since the first PAL-conference in 1995 and shows the latest innovative potentials of the automotive industry in the application of lighting technologies.

These proceedings result from the work of a lot of experts in the automotive and optical industry, administrative bodies, research institutes and universities. It summarizes the findings of more than 200 authors and co-authors and gives a scope of their expectations for the future. In 2019, the ISAL Steering Board could identify the following focus topics:

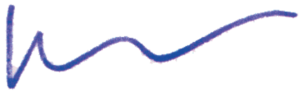
- Light source technology generally with the latest innovations in Laser and LED modules
- High Resolution Headlamps and Digital Light
- Road Projections
- Communication between automated vehicles and other road users
- Headlamp Rating Systems

While in the last couple of years, focus was placed high-resolution headlamps and this topic still remains relevant today, the most pressing topic for this year's ISAL is the visual communication between automated vehicles and other road users. While this topic includes the general question, if communication is necessary emphasis is also placed on how, when and where communication is needed. Another strong topic for this year's symposium is the ongoing investigation on road projection and its benefit for the driver. What kind of symbols should be projected onto the road in front of the driver and what benefit do they lead to?

Similar to ISAL 2017, ISAL 2019, will host a podium discussion on the latest research regarding the communication between automated vehicles and other road users. Discussing different findings over the last two years and the consequences for automotive lighting due to that.

We wish you a very informative and successful ISAL 2019 in Darmstadt. We hope that this year's event and these proceedings will give you inspiration and motivation for your work during the next 24 months.

Yours sincerely,



Prof. Dr.-Ing. habil. Tran Quoc Khanh

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I. General Headlamps Topics

Optical Concepts with Slim Lenses for Design Driven Headlamps

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Keywords: headlamp, lighting, slim, modules, micro lens array, MLA, integrated optics

1 Abstract

We are looking at the trend of slim modules for the next generation of design driven headlamps. Especially the lens height is decreasing with each generation of head lamps. The main driving factor for this trend is styling, but also the increased number of modules per headlamp. Improvements of the production processes of lenses make way for this trend, but the impact on lighting performance must be considered also. Upcoming headlamps cannot compromise in this regard, since the main light functions are an important safety and comfort feature. The introduction of the IIHS rating and its impact is a good example.

We are looking at the impact of reduced lens size on existing optical concepts to understand the challenges in this development. A slim lens means a reduced optical efficiency and increased power consumption of the headlamp. Nevertheless, electro mobility and reduction of emissions make it necessary to keep the power consumption low. New optical concepts are needed for this.

A prominent topic is micro-lens arrays (MLA), but there are many more technology advancements which will help shrinking the lens size. Reducing the size of the light source helps to reduce the module size. Choosing the right optical system for different applications with slim lenses is the key factor. Refraction, diffraction and total internal reflection (TIR) have different advantages. Additional technologies like anti-reflection treatment must be considered also.

2 Introduction

Figure 1.: Depiction of headlamp with slim and wide modules. This is an exemplary design for the current trend in headlamps

There is a clear styling trend for more and more slim modules within headlamps. Figure 1 shows a styling which is typical for current concepts cars. Very slim modules are integrated to the lit-up appearance, which was formally mostly done by the daytime running lights. Now the lit-up modules themselves are part of the styling, leading to complicated and small lens sizes. The loss of total lens size, but also the strong deviation from a round shape are impacting the optical system.

Especially with the introduction of plastic lenses more and more complicated shapes were possible. Even glass lenses became more flexible in terms of lens shape, but less than plastic. But the lenses are only part of the solution. The optical concepts behind the lens must keep up with the trend. Since lighting is a major safety factor the performance of the modules can not be sacrificed. Especially for complex systems like ADB, AFS and powerful high beams it is a challenge to make them possible behind such small lenses.

The optical solutions right now on the market usually allow for lenses with a height of at least 30mm – 40mm. Further optimization of these allow to have modules with 20mm high lenses. Measures which help to achieve this are described in section 4. Going down to 15mm or even 10mm requires solutions which differ from the standards. These are described in section 5 and 6.

3 Current solutions

The generation of modules on the market caters to the beginning of these design requirements by splitting the optic system in a fixed base and a flexible lens. A core module is developed in a way that it functions with a wide array of lens shapes. In terms of optics the core consists of the Leds and a primary optic, typically a TIR or a reflector optic. This is designed in a way that the whole lens is utilized.

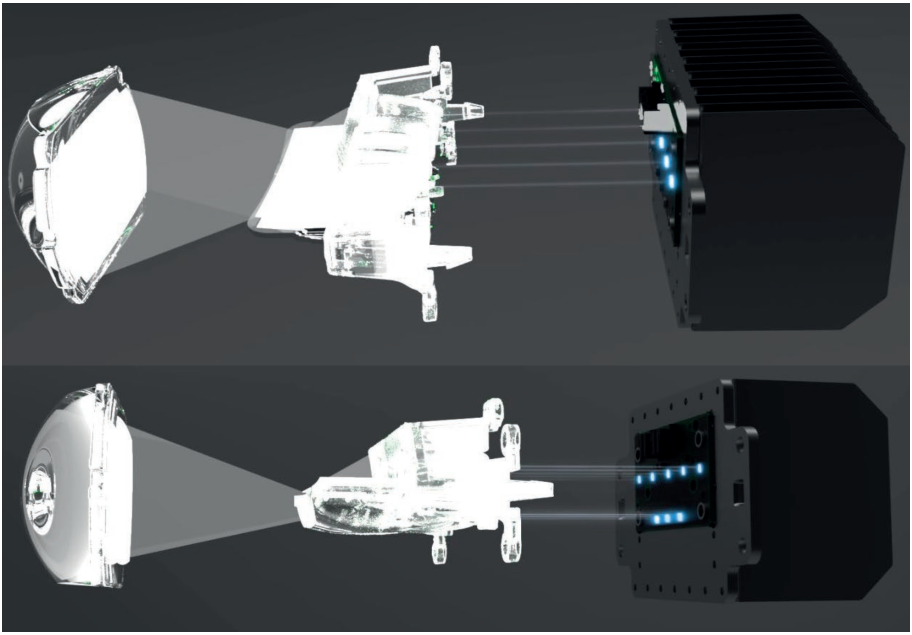

Figure 2.: Exploded view of a current generation BiLed. Top shows a sketch of the light path of the low beam and bottom shows the light path of the high beam

As shown in figure 2 the light cone of the primary optics utilized a typical lens size (e.g. 70mm x 50mm). Increasing and decreasing the lens size scales the performance in terms of light flux and intensity, but the overall light distribution remains the same. By changing the number of leds and the light output of the leds the losses from small lenses can even be compensated. As shown in figure 3 this works for quite a range of lens sizes. At a certain point not only light flux is lost but main features of the light distribution are lost in total and the module does not work for this lens size. For example, an exemplary BiLed module works down to a lens size of 60mm x 40mm, but at 60mm x 30mm it is reduced to a low beam, because most the light(-rays) from the high beam are lost. More advanced modules, like matrix systems, typically need even bigger lens sizes for an acceptable performance.

In case the lens is to small for the primary optics concept optimized solutions are necessary. For the E and F segment tailored solutions can be found and are already on the road. Nevertheless, since slim modules is a general trend flexible solution for all kind of light functions are necessary. For complex optical systems like ADB modules this is a challenging task. In the next sections technologies are summarized, which can solve this.

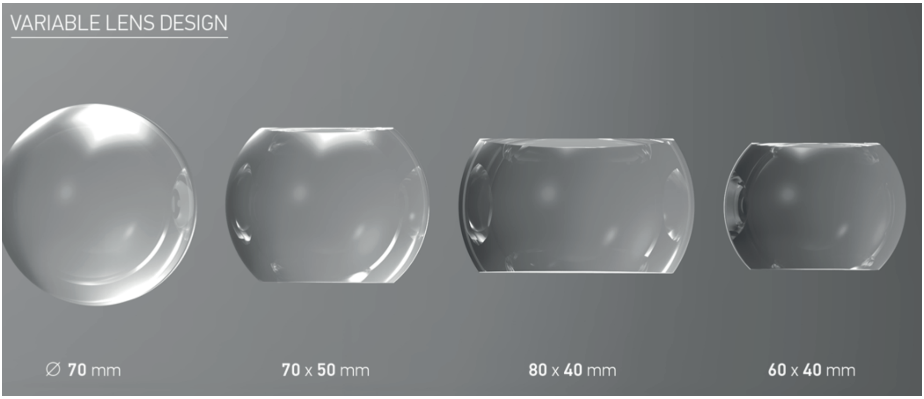

Figure 3.: Variations of lens sizes which work as a secondary optic for a module. Total surface and the height shows a big variation

4 Optimized solutions

The main challenge for small lenses is the optical efficiency of the module. Smaller lens size means a smaller aperture of the optical system. To regain the optical efficiency, there are several options. Counteracting by increasing the light flux from the leds is not sufficient, since this is limited by thermal requirements, power consumptions and finally cost.

Optimizing the existing optical concepts on smaller and design shaped lenses usually allows for a better optical efficiency. Often the flexibility of the system must be sacrificed in this case. Decreasing the focal lens as much as possible is one way to keep efficiency high. In many cases this is not an option, because it would lower the maximum intensity of the light function. Ratings like IIHS need a high maximum intensity.

Antireflection treatment on the optical components is a way to increase the optical efficiency of any system. Usually, 4% are lost per material-material-transition. Most optic concepts are based on two optical components with four transitions in total. So about 16% efficiency can be gained by antireflection treatment. Although anti reflection treatments are in general an established technology there are challenges for the application in head lamps. High temperatures can impact coatings or melt fine structures. Primary optics shapes differ vastly from flat or spherical shapes from lenses, which makes a treatment more complicated. There are many promising advancements in the industry and once a good solution is found many modules at the same time will profit from it.

The increase of intensity of light sources is another option to shrink the size of modules. With smaller light sources the size of the other optics can be scaled down accordingly. Laser light sources are popular for a very high intensity, which makes powerful but compact high beam spots possible. Leds are also available with higher and higher intensity in each generation. This trend is somewhat limited, because plastic optics are not able to withstand the high intensities. For standard applications glass optics and reflectors are a good solution. For more advanced optics shapes, e.g. necessary for matrix modules, silicon is a good choice. It can be molded in fine shapes and can withstand high intensities at the same time.

Based on the existing solutions optimized components allow for a lens height down to 20mm for most applications like a BiLed or single row matrix module. To go below this lens height new solutions are necessary which are presented in the next sections.

5 Integrated Optics

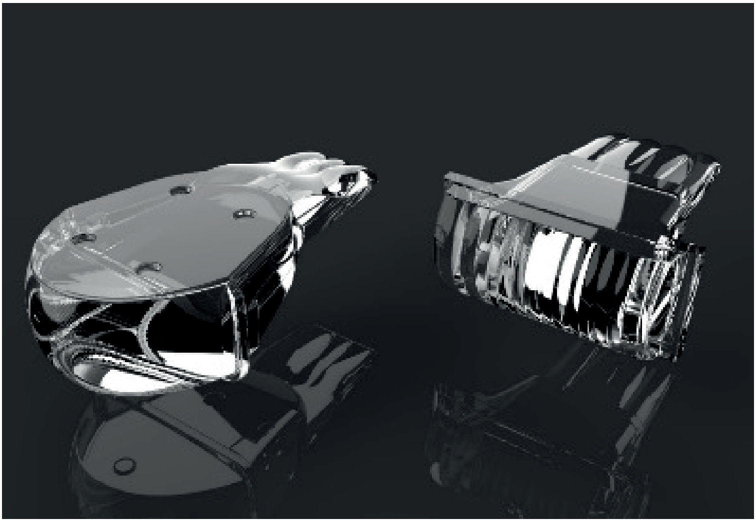

Figure 4.: Set of modules based on integrated optics. The left one is a low beam range with good imaging properties. The right one is a prefield optimized for a high spread of the light distribution.

Integrated optics is an example of a specialized solution. Already on the market this set of modules, called ComLeds, allows for a good light performance with 27mm high lenses. The optical efficiency with >50% is exceptional for this size. Although started as a specialized solution, advancements in this technology make it a promising candidate for a wide array of application as slim modules.

The optics consist of one solid body, which solves three tasks at once. The incoupling side of the Leds collects and directs the light via TIR into the imaging plane, which is about in the middle of the optics. In the imaging plane the shape of the COL is cut into the optics. At the outcoupling side the optics is formed so that the imaging plane is projected onto the street. Either it is aspheric shaped as the left optic in figure 4 for ideal imaging properties or it is optimized for a high spread of the light distribution as shown on the right.

The design of this module allows for a high optical efficiency. First, TIR has very little losses while collecting the Led light. Second, there are no material transitions within the optics, so there are no Fresnel losses.